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New information on earthquake history of the Aksehir-Afyon Graben System, Turkey, since the second half of 18th century

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Abstract. Researches aimed at enriching the number of available documentary sources on earthquakes have an important role in seismology. To this end, this paper documents the history of prominent earthquakes associated with the NW-SE trending Sultandag-Aksehir Fault and Aksehir-Afyon graben system in Western-Central Anatolia since the historical times through 1766. This work also combines the earthquake data for both historical and instrumental periods, previously listed in various catalogues and resources, for the studied area.

Documents from the Ottoman archives and libraries as well as the Ottoman and Turkish newspapers were scrutinized, and eight previously unreported earthquakes in the latter half of the nineteenth century and four new earthquakes in the period 1900–1931 were revealed. For the period from 1766 to 1931, the total number of known earthquakes for the area under investigation increased from eighteen to thirty thanks to the document search. Furthermore, the existing information on eleven previously reported earthquakes is updated for the period from 1862 to 1946. Earthquakes from 1946 to 1964 are compiled from the catalogues for data completeness.

1 Introduction

The Aksehir-Afyon Graben (AAG) is 4–20 km wide, 130 km long, has a NW-trending depression zone, and has been developing since the Pliocene (Fig. 1). The Sultandag-Aksehir Fault (SAF) is the main border fault on the SW side of the AAG, with a dip slip rate of 0.3 mm/y (Kocyigit and Ozacar, 2003). The investigation area has encountered a series of damaging earthquakes in its history. The most recent seismic activity in the area started with the 15 De-

cember 2000 Sultandagi-Aksehir Earthquake ($M_w=6.0$) and continued with the 3 February 2002 Cay-Eber Earthquake ($M_w=6.5$). Aftershocks on the same day (3 February 2002) included the $M_w=5.8$ Cobanlar earthquake, a $M_d=5.1$ and a $M_d=5.0$ events. While investigating the aftershock behaviour of these earthquakes (Ozer et al., 2002a, b; Ozer and Altinok, 2004), a better evaluation of the seismic activity in the past has been a requirement. This paper is the result of this research on the earthquake history of the region.

The information on earthquakes in the area and environs dates as far back as 94 AD, but there is a distinct dearth of data for the period between 94 and 1766 (Altinok, 2003). In order to better establish the completeness and accuracy of the historical seismic record for this area for the period from 1766 to the present, archival records including official document and newspapers from both the Ottoman and subsequent periods, were searched, on which basis new earthquake data have been compiled. The data after 1964 is not covered in this work and it can be easily obtained from the bulletins of the related data centres. There have been fortyfive earthquakes located in the AAG between the years 1766 and 1964. These earthquakes caused damages in the localities of Afyon, Suhut, Bolvadin, Aksehir, Argithani, Ilgin and Yalvac. The most prominent earthquakes among these were the ones that occurred in 1766, 3 November 1862, July–October 1866, 1911, 4 October 1914, 26 September 1921, 28 January 1931, 9 April 1931, and 21 February 1946. Additionally, the earthquakes of November 1862, 1911, 4 October 1914 and 28 January 1931 created surface cracks. The Heybeli Kizilkilise hot springs were also initiated by the 1911 earthquake.

Within this work, twelve previously unreported earthquakes were identified, and information on eleven previously reported earthquakes was updated. The intensities for the newly revealed earthquakes are not assigned, as the obtained data is not adequate.

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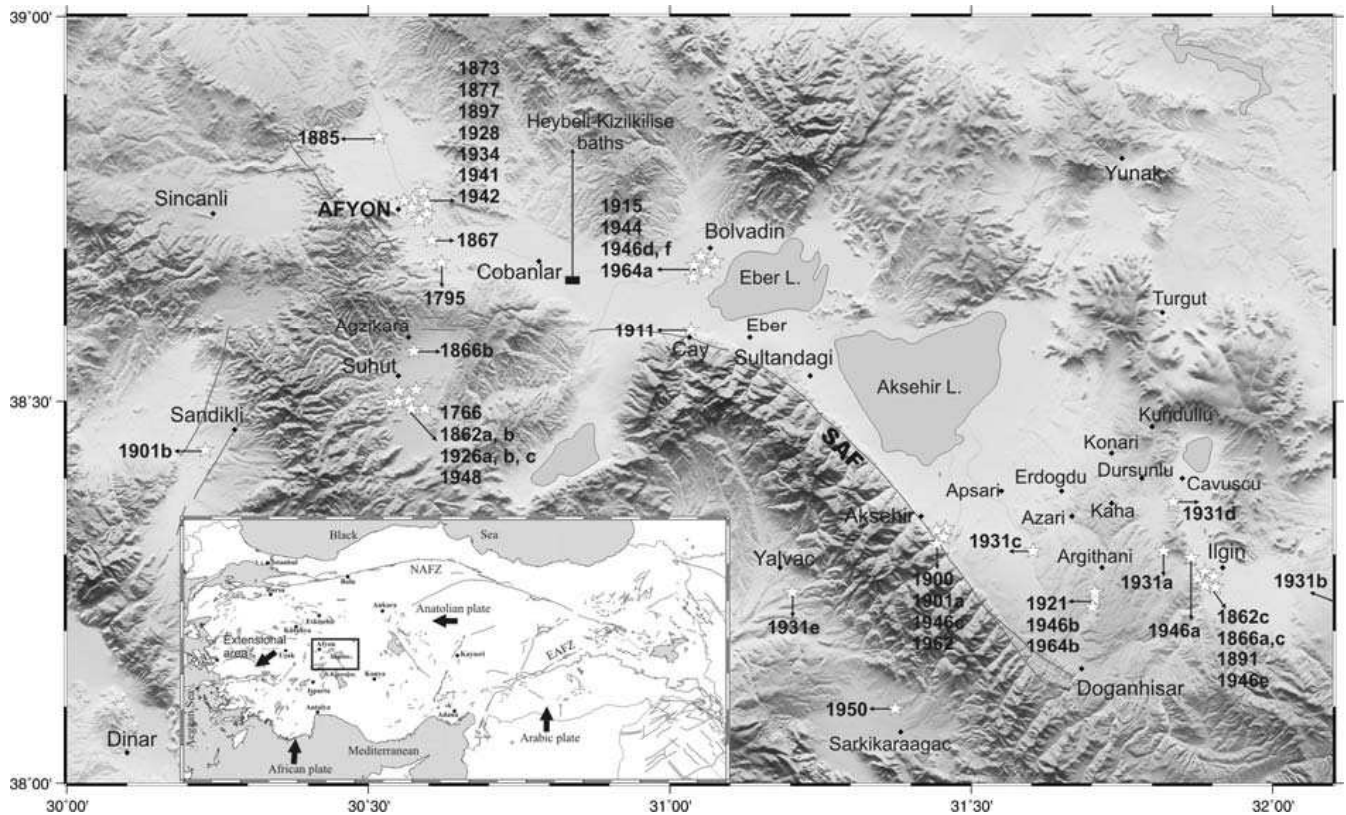


Fig. 1. The locations of the earthquakes that occurred in the study area from 1766 to 1964. Diamonds show the settlements. White stars indicate the assigned epicenters by this study. The small rectangle and bold arrows in the inset map show the location of the area and the direction of plate movements, respectively. SAF; Sultandag-Aksehir Fault, NAFZ; North Anatolian Fault Zone, EAFZ; East Anatolian Fault Zone. Tectonic features in the maps are from Saroglu et al. (1987) and Barka (1992).

2 Data and information sources used in the study

Data and information about previously enrolled seismic events in the area were obtained from various catalogues and articles, including the studies of Pinar and Lahn (1952), Ocal (1968a, b), Soysal et al. (1981), Ambraseys and Finkel (1987), Ambraseys (1988), and Eyidogan et al. (1991). Various archives and historical records, specifically the Ottoman Archives and the records in Turkish Republic Prime Ministry-General Directorate of the State Archives (BOA), Istanbul Beyazit State Library, and Istanbul Atatürk Library were systematically examined. Furthermore, thirtyfive different newspapers in Modern and Ottoman Turkish, and European languages were searched for reports of earthquakes in the study area.

3 Historical seismicity assessed from archival research

The data obtained from archival sources concerning the seismicity of the area under investigation are provided below. Descriptions of earthquake effects were translated verbatim from the original sources.

Twelve previously unreported earthquakes were identified on the basis of information in records from the Ottoman archives and state libraries. These are the earthquakes of 14 November 1862, November/December 1862, 26/27 January 1866, 5 May 1866, October (?) 1867, 23 December 1877, 28 November 1885, 27 March 1891, 25 April 1900, 11 October 1901, 2 February 1915, and 29 July 1931.

New information was found concerning eleven previously reported earthquakes, which as a result are now better documented. These are the 3 November 1862, July–October 1866, April 1901, 4 October 1914, 26 September 1921, 9 April 1931, 19 November 1934, 29 January 1941, 18 January 1942, 21 February 1946, and 18 March 1946 earthquakes.

The epicenters of these earthquakes are assigned according to the obtained information by the study (Fig. 1). Where the epicenter is uncertain, either the town that experienced the highest intensity, or the area where it was felt, is indicated. In some cases, the new data confirms the previously indicated locations. The determination or revision of earthquake magnitude, however, is beyond the scope of this work.

The earthquake information obtained within the study is grouped under two sub-topics as “newly revealed” and

“updated” below. In addition, in order to provide the completeness of catalogue, the earthquakes which are mentioned in previous studies, catalogues and reports but not updated by this paper, are summarized under the topic of “previously listed earthquakes”. Consequently, a final table including all earthquakes is prepared (Table 1). The earthquakes in the same year are distinguished by the codes assigned to them as the year followed by a letter (e.g. 1862b indicates the second earthquake in 1862). I_0 is the maximum intensity degree at the epicenter in Mercalli-Sieberg scale. The plus signs next to the intensities (e.g. V+) indicate slightly larger than the given values at a few locations.

3.1 Newly revealed earthquakes

14 November 1862 11:40 a.m. (local time) – Suhut

A strong earthquake occurred in Suhut, with no casualties. The walls that were damaged in the previous earthquake of 3 November 1862 were collapsed (BOA, A.MKT.MHM., 354/43).

November/December 1862 – Ilgin

Sequential earthquakes occurred in the town of Ilgin, resulting in the damage of some houses and walls. The bridge on the Posta Street had cracks on it (BOA, A.MKT.MHM., 249/4).

26/27 January 1866 – Ilgin

From the 10th day of Ramadan onward, a series of earthquakes occurred in Ilgin. Five earthquakes occurred on 1/2 March 1866, four earthquakes during the night of 2/3 March, and ten earthquakes on 6/7 March. On the following day at 08:00 a.m. (local time) intensive shocks that resembled 5–10 cannon blasts were felt. On 21/22 March 1866, a strong earthquake occurred at 06:00 in the morning, and damaged the gallery of the Pir Hasan mosque, resulting in an eastward inclination. Twenty houses and some walls of houses collapsed, but no human casualties were recorded. A nearby hot spring flowed discontinuously and the water level of local wells dropped. The bridge on the Posta Street had cracks on it (BOA, A.MKT.MHM., 354/43).

5 May 1866 Sunday 08:30 a.m. (local time) – Suhut, Agzikara

In the morning, the gallery of the minaret of the big mosque in Suhut cracked. Some old walls collapsed. In the village of Agzikara, barns collapsed and animals were killed. No human casualties were recorded (BOA, A.MKT.MHM., 358/100).

Table 1. History of the earthquakes in the studied area. N, U and P in the “Status” column represent newly revealed, updated and previously listed earthquakes, respectively.

No	Date	Code in map	Location	Status
1	1766	1766	Afyon, Suhut	P
2	1795 (?)	1795	Afyon	P
3	3 Nov 1862	1862a	Suhut	U
4	14 Nov 1862	1862b	Suhut	N
5	Nov/Dec 1862	1862c	Ilgin	N
6	26/27 Jan 1866	1866a	Ilgin	N
7	5 May 1866	1866b	Suhut, Agzikara	N
8	July–Oct 1866	1866c	Ilgin	U
9	Oct (?) 1867	1867	Afyon	N
10	1 Oct 1873	1873	Afyon	P
11	23 Dec 1877	1877	Afyon	N
12	28 Nov 1885	1885	Afyon	N
13	27 Mar 1891	1891	Ilgin	N
14	23 May 1897	1897	Afyon	P
15	25 Apr 1900	1900	Aksehir	N
16	April 1901	1901a	Aksehir	U
17	11 Oct 1901	1901b	?	N
18	1911	1911	Afyon, Bolvadin, Cay	P
19	4 Oct 1914	Not in map	Burdur	U
20	2 Feb 1915	1915	Bolvadin	N
21	26 Sep 1921	1921	Argithani, Aksehir	U
22	9 Jul 1926	1926a	Suhut	P
23	13 Jul 1926	1926b	Suhut	P
24	24 Aug 1926	1926c	Suhut	P
25	Nov 1928	1928	Afyon	P
26	11 Jan 1931	1931a	Argithani	P
27	12 Jan 1931	1931b	Kadinhani	P
28	28 Jan 1931	1931c	Aksehir	P
29	9 April 1931	1931d	Ilgin	U
30	29 Jul 1931	1931e	Yalvac	N
31	19 Nov 1934	1934	Afyon	U
32	29 Jan 1941	1941	Afyon	U
33	18 Jan 1942	1942	Afyon	U
34	19 Dec 1944	1944	Bolvadin	P
35	21 Feb 1946	1946a	Ilgin, Argithani	U
36	18 March 1946	1946b	Argithani	U
37	30 March 1946	1946c	Aksehir	P
38	16 July 1946	1946d	Bolvadin	P
39	17 July 1946	1946e	Ilgin	P
40	11 Sep 1946	1946f	Bolvadin	P
41	4 Dec 1948	1948	Suhut	P
42	4 Aug 1950	1950	Sarkikaraagac	P
43	29 July 1962	1962	Aksehir	P
44	16 Jan 1964	1964a	Bolvadin	P
45	26 Nov 1964	1964b	Argithani	P

October (?) 1867 – Afyon

An earthquake occurred in Afyon (BOA, A.MKT.MHM., 391/89).

23 December 1877 – Afyon

A strong earthquake occurred in Afyon at around 11:00 a.m. (local time) on Sunday. Two walls and a meeting house collapsed but no human casualties were recorded (Basiret, 29 December 1877).

28 November 1885 – Afyon

Four earthquakes occurred in Afyon and two of them were rather severe. A few days later, another earthquake occurred and created surface ruptures in the village of Koprucoren (Gumus-Kutahya) (Tercuman-i Hakikat, 6/7 December 1885).

27 March 1891 – Ilgin

A strong earthquake occurred in the town of Ilgin around 11:00 a.m. with local time on Wednesday. It lasted 2 s. No damage was recorded (Takvim-i Vekayi, 30 April 1891).

25 April 1900 – Aksehir

Two earthquakes occurred in Aksehir, one of which was rather strong (Ikdam, 28 April 1900).

11 October 1901 – ?

An earthquake was felt in Sandikli, Dinar, Suhut, Sincanli, and the surrounding villages (Sabah, 12 October 1901).

2 February 1915 – Bolvadin

An earthquake occurred in Bolvadin (BOA, DH.EUM.VRK., 14/59).

29 July 1931 – Yalvac

An earthquake that lasted 4 s occurred in Yalvac. Three houses were destroyed on Soburcayir farm (Yenigun, 10 August 1931).

3.2 Updated earthquakes*3 November 1862 – Suhut*

At first, slight tremors were felt. Three days later, a strong earthquake occurred and destroyed a large part of the town of Suhut, which is situated on alluvium. There were 800 casualties. Water spurted out of cracks in the ground. The epicenter was on the Suhut Plain and the earthquake was strongly felt in Dinar, Afyon, and Konya (Pinar and Lahn, 1952). The date of the earthquake is given as 1863 by Pinar and Lahn (1952). Soysal et al. (1981) record the date as 16 October 1862. Nine shocks occurred from the evening to the following morning and activity continued for two days. Earthquake caused damage particularly in Suhut, and destroyed 15 quarters causing 286 casualties. A mosque in Afyon was also damaged (Tercuman-i Ahval, 11/12 November 1862; Ceride-i Havadis, 16/17 November 1862).

July–October 1866 – Ilgin

The epicenter may have been in the Ilgin region (Pinar and Lahn, 1952). A total of 34 buildings turned into rub-

ble. The bridge on the Posta Street collapsed, too (BOA, A.MKT.MHM., 365/80).

April 1901 – Aksehir

A strong earthquake occurred in Aksehir (Pinar and Lahn, 1952). Another shock occurred in Isparta and Burdur, and was felt from the south to the north, on 3 April 1901, at around 04:00 h (local time). On 4 April 1901 at 17:30, one more earthquake was felt in Isparta, from north to south (Ikdam, 27 April 1901).

4 October 1914 – Burdur

The Great Burdur Earthquake (00:05 local time, $M_S=7.0$; Ambraseys and Finkel, 1987). Although the epicenter of this earthquake is not in the investigation region, it is included since its effects in the study area were rather high. The earthquake was felt with various intensities in Konya, Yenisehir, Ilgin, Aksehir, Seydisehir, Antalya, Denizli, Civril, Bolvadin, Alasehir, and Kutahya. There was a great number of casualties in Burdur, Isparta, Dinar, and their surrounding villages, and extensive damage occurred. 2344 deaths were recorded and about 10 000 families rendered homeless. The large number of casualties was due to the fact that the houses were constructed with adobe and ceilings made of thick heavy mud. A 40-km-long crack, oriented SW–NE, was opened in the ground running parallel to the edge of the Burdur Lake. The epicenter was proposed to be along the crack in the Burdur Plain. The aftershocks lasted three months. In the area between Bolvadin and Cay about 100 houses were destroyed, and a new hot spring formed in the Heybeli Kizilkilise Baths (Pinar and Lahn, 1952; Cakici, 2001).

26 September 1921 – Argithani, Aksehir

The Argithani-Aksehir Earthquake ($M_S=5.9$, 09:25:55 (UTC); Ambraseys, 1988). The earthquake occurred on the fault towards the west of the Ilgin Lake, near the Cavuscu Village, and caused significant damage to residences in the area between Argithani, Kondullu (Kundullu), and Doganhisar. The Cavuscu train station building was also damaged, despite its strong limestone foundation (Chaput, 1936; Pinar and Lahn, 1952). The most affected area was Sarkikaraagac, and strong shocks occurred in the direction from Doganhisar to Argithani, Dursunlu, Konari, Kundullu, Kaha, through to Turgut. The earthquake was felt slightly in Aksehir and Ilgin (Sanir, 1948).

9 April 1931 – Ilgin

The Ilgin Earthquake ($M=6.1$, Ocal, 1968a). The earthquake caused less damage over a smaller area as compared with the 1921 earthquake which was related to the Cavuscu fault. The Cavuscu train station building was once again damaged and

was therefore transferred to Argithani (Chaput, 1936; Pinar and Lahn, 1952; Ocal, 1968a). Significant damage occurred in Cavuscu and Argithani (Sanir, 1948).

19 November 1934 – Afyon

A local earthquake occurred in Afyon but it caused no damage (Pinar and Lahn, 1952). Aftershocks continued and a slight tremor was felt on 23 November at 11:30 with local time (Aksam, 26 November 1934).

29 January 1941 – Afyon

An intense earthquake occurred in Afyon but caused no damage (Pinar and Lahn, 1952). $I_0=V$ (Ocal, 1968a). The earthquake occurred at 15:50 (local time) in Afyon and did not cause any damage (Ulus, 31 January 1941).

18 January 1942 – Afyon

A low-intensity earthquake occurred in Afyon (Pinar and Lahn, 1952). A strong earthquake occurred in Afyon at 15:30 (local time) and did not cause any damage (Cumhuriyet, 19 January 1942; Ikdam, 19 January 1942).

21 February 1946 – Ilgin, Argithani

The Ilgin-Argithani Earthquake ($M_S=5.7$, 15:43:04 (UTC); Ambraseys, 1988). The earthquake, which lasted 15 s, was felt in Ankara, Eskisehir, Kutahya, Istanbul, Bolu, Bursa, Konya, Aksehir, Sarkikaraagac, and Bolvadin. The localities most affected by the earthquake included Azari, Kaha, Dursunlu, Erdogdu, Melles, Apsari, and Argithani. The earthquake consisted of two shocks separated by an interval of 12 min (Sanir, 1948). The epicenter was situated in the north of the Cavuscu Village, on the fault passing towards the west of the Ilgin Lake. Extensive damage occurred in Argithani, Cavuscu and Tursunlu, whereas light damage was sustained in Doganhisar, Urus, and Ilgin. A total of 12 people were killed and 9 were injured. In Argithani, 90 residences were demolished and 350 were rendered uninhabitable; in Ilgin 24 residences were destroyed; and in Erdogdu village 63 houses and a village mansion were destroyed (Vakit, 23 February 1946; Yeni Sabah, 23 February 1946; Pinar and Lahn, 1952; Eyidogan et al., 1991). Another earthquake that occurred between 19:50–20:00 h was felt in Ankara, Aksehir, Bursa, Bolvadin and Konya (Vakit, 23 February 1946; Son Posta, 23 February 1946; Ulus, 22 February 1946; Aksam, 23 February 1946).

18 March 1946 – Argithani

Argithani. $I_0=IV-V$ (Ocal, 1968a). Two strong earthquakes occurred at 14h with local time (Son Posta, 19 March 1946).

3.3 Previously listed earthquakes

1766 – Afyon, Suhut

The earthquake caused damage in Suhut. The epicenter may have been on the Suhut Plain (Pinar and Lahn, 1952).

1795 (?) – Afyon

The epicenter may be in the AAG near Afyon, but the date of the event is uncertain. An epigraph states that the Gedik Ahmet Pasa mosque (Afyon) which had been damaged a few years before 1795 was repaired in 1795 (Pinar and Lahn, 1952).

1 October 1873 – Afyon

Local earthquake in Afyon (Pinar and Lahn, 1952).

23 May 1897 – Afyon

An earthquake occurred at 02:55 (UTC), $I_0=IV$ (Ocal, 1968a).

1911 – Afyon, Bolvadin, Cay

The earthquake, which occurred in the Aksehir-Afyon Graben, caused various damage. Hot springs near the Heybeli-Kizilkilise Baths were initiated by the earthquake (Pinar and Lahn, 1952).

9 July 1926 – Suhut

$I_0=V+$ (Ocal, 1968a).

13 July 1926 – Suhut

$I_0=V+$ (Ocal, 1968a).

24 August 1926 – Suhut

$I_0=V+$ (Ocal, 1968a).

November 1928 – Afyon

A high-intensity earthquake in Afyon with no damage (Pinar and Lahn, 1952).

11, 12, 28 January 1931 – Argithani, Kadinhani, Aksehir

In Argithani, 60 houses were damaged by the earthquake of 11 January ($M=4.9$). The second event occurred in Kadinhani on 12 January at 15:06 local time ($M=4.0$). On 28 January, an earthquake occurred in Aksehir, causing damage. In Aksehir and its villages, 154 houses and 220 barns collapsed, while in Ilgin and environs 85 houses and 4 barns were damaged ($M=5.5$). Surface ruptures appeared at Cavuskoy (Ocal, 1968a).

19 December 1944 – Bolvadin

Origin time 02:58 (UTC), I_0 = IV–V (Ocal, 1968a).

30 March 1946 – Aksehir

Origin time 15:10 (UTC), I_0 = III–IV (Ocal, 1968a).

16 July 1946 – Bolvadin

I_0 = IV–V (Ocal, 1968a).

17 July 1946 – Ilgin

Origin time 19:45, I_0 = V (Ocal, 1968a).

11 September 1946 – Bolvadin

Origin time 04:48 (UTC), I_0 = IV (Ocal, 1968a).

4 December 1948 – Suhut

Origin time 03:40 (UTC), I_0 = III–IV (Ocal, 1968a).

4 August 1950 – Sarkikaraagac

Origin time 08:40 (UTC), I_0 = III (Ocal, 1968a).

29 July 1962 – Aksehir

Origin time 04:30 (UTC), I_0 = IV (Ocal, 1968b).

16 January 1964 – Bolvadin

Origin time 15:01 (UTC), I_0 = III–IV (Ocal, 1968b).

26 November 1964 – Argithani

Origin time 21:00 (UTC), I_0 = IV (Ocal, 1968b).

4 Discussion

The results obtained from this historical record search are very encouraging. For the study area, eight new earthquakes prior to 1900 were revealed, adding to the six already reported in existing catalogues for the same period. Six of the new earthquakes are reported as having “caused collapse of structures and damage”, while the other two are simply reported as “having occurred”. For the period between 1900 and 1931, four new earthquakes were found compared to the twelve previously identified earthquakes. Reports of the earthquakes of 14 November 1862, 28 November 1885, October (?) 1867, 27 March 1891, 25 April 1900, 11 October 1901, 2 February 1915, and 29 July 1931 did not show any information regarding damage. Four other new earthquakes, those of November/December 1862, 5 May 1866 and 23 December 1877 caused damage, while the earthquake of

26/27 January 1866 also created cracks in the ground and hot springs.

The most recent prominent regional event prior to 15 December 2000 earthquake was the 21 February 1946 Ilgin-Argithani earthquake ($M_S=5.7$), the epicenter of which was located at the southeastern end of the Aksehir-Afyon graben. Another earthquake occurred in 1911 near the towns of Cay and Eber (Afyon), where the 2002 macroseismic epicenter was also located. The Heybeli Kizilkilise hot spring was initiated by the 1911 earthquake, and reactivated by the 1914 Great Burdur earthquake and the 2002 earthquake sequences. The new data indicate that the most affected places in the AAG are Suhut near the western end of the SAF, and Ilgin and Argithani located near its eastern end.

5 Conclusions

This study has documented previously unreported earthquakes in the vicinity of the Sultandag-Aksehir Fault in the Aksehir-Afyon Graben, Turkey, using archival and library research. For the study area, eight new earthquakes prior to 1900 were identified, adding to the six already documented ones and four new earthquakes were found for the period from 1900 to 1931, adding to the twelve already known ones. The results of this study clearly demonstrate that additional archival searches could further improve the accuracy and coverage of historical seismicity for the study area as well as other areas of Turkey. Such studies should increase the knowledge of relationship between existing faults and historical seismicity, and should also improve the seismic hazard assessments.

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Press:

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Ikdam 28 April 1900.
Ikdam 27 April 1901.
Ikdam, 19 January 1942.
Sabah, 12 October 1901.
Son Posta, 23 February 1946.
Son Posta, 19 March 1946.
Takvim-i Vekayi, 30 April 1891.
Tercuman-i Ahval, 11/12 November 1862.
Tercuman-i Hakikat, 6/7 December 1885.
Ulus, 31 January 1941.
Ulus, 22 February 1946.
Vakit, 23 February 1946.
Yenigun, 10 August 1931.
Yeni Sabah, 23 February 1946.